

MULTIPLE INJECTIONS FOR ANGIOCARDIOGRAPHY

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In the past the value of angiocardiology has been limited by the practice of giving only one injection of contrast medium, so that selective angiocardiology tends to be restricted to the end of cardiac catheterization. Moreover, the use of biplane film changers permits only views strictly at right angles to one another.

The newer contrast media are tolerated better than those formerly available and multiple injections can now be employed. As this is still not universal practice it was thought worth while to record experiences with high doses of hypaque and triosil.

DATA

The data from the last 500 examinations have been analysed. All but 2 were children with ages ranging from 1 week to 15 years.

Multiple injections (Table I) were used in most of these examinations.

TABLE I

THE NUMBER OF CONTRAST INJECTIONS USED IN 500 EXAMINATIONS

Number of injections	Examinations
1	77
2	305
3	78
4	28
5	8
6	4

The type of contrast medium was recorded in 495 examinations: in 483 all the injections were of high concentration media, 195 having 85 per cent hypaque (sodium and N-methylglucamine salts of diatrizoic acid) and 287 having 75 per cent triosil (sodium metrizoate). In addition one child received injections of both of these media, which are exactly comparable in their iodine content (0.44 g. iodine/ml.). The remaining 12 children were given more dilute media. The basic dose used was 1.5 ml./kg. for each injection. This amount was used when injecting into the superior vena cava (when full cardiac catheterization was not being attempted), into the right atrium, or into the right ventricle. Injections into the left atrium or left ventricle were usually smaller (1.0 ml./kg.) and those into the aorta smaller still. The calculated dose was varied somewhat in either direction according to the size of the heart and for convenience in using available sizes of metal injection syringes. Nearly all injections were made with the aid of a pneumatic injector. Some of the catheters used had end holes and others had both end and side holes.

The quantities employed were recorded in 392 examinations and the total doses received, calculated in ml./kg. body weight, are shown in Table II and Fig. 1. The average dose of concentrated medium was just

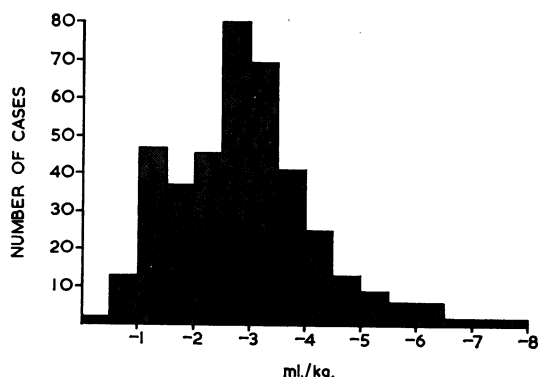


FIG. 1.—Total dosage of contrast medium.

over 2.9 ml./kg. and in nearly 20 per cent of the examinations the total dose lay between 2.5 and 3 ml. In 63 per cent of the examinations the dose of concentrated medium exceeded 2.5 ml. and in 84 per cent it exceeded 1.5 ml.

These figures contrast strongly with the more usual dosage of 1.0 to 1.5 ml./kg. body weight employed in most centres where angiocardio-graphy is restricted to a single injection. However, no complications could be attributed to the contrast medium in spite of high doses and multiple injections. Minor complications were caused occasionally by the sudden recoil of the catheter, especially when it jumped back into the right atrium (in two cases a little contrast medium leaked into the pericardium and several times small quantities entered the myocardium;

temporary asystole, lasting a few seconds, occurred once). None of the children showed any outward disturbance or caused anxiety, either at the time or subsequently.

RESULTS

It is important to inquire whether there are factors other than the improved characteristics of the media that have contributed to safety. The patients have varied considerably in size and general condition. Many children were severely ill with intense cyanosis and/or great cardiac enlargement. Indeed, we have been so impressed by the safety of the procedure that, when dealing with small bad risk infants, we have preferred angiocardio-graphy, with two caval injections, to full cardiac catheterization.

There has been no special period of waiting between contrast injections; frequently they have followed one another as quickly as the syringe could be recharged.

TABLE II
THE TOTAL DOSAGE OF CONTRAST MEDIA IN 392 EXAMINATIONS

Total dose (ml./kg.)	Number of examinations			
	Dilute media†	Hypaque 85%	Triosil 75%	Total
-0.5	0	0	1	1
-1.0	1	4	8	13
-1.5	2	21	24	47
-2.0	2	11	24	37
-2.5	1	15	28	44
-3.0	3	25	52	80
-3.5	0	25	44	69
-4.0	1	16	24	41
-4.5	0	5	20	25
-5.0	1	4	8	13
-5.5	0	1	8	9
-6.0	0	0	5	5
-6.5	1	0	4	5
-7.0	0	0	1	1
-7.5	0	0	1	1
-8.0	0	0	1	1
Totals	12	127	253	392

† Details of dilute media

Hypaque 45% and 65%	..	1	examination/s
Hypaque 65%	..	6	„
Hypaque 65% and 85%	..	3	„
Triosil 50%	..	1	„
Triosil 50% and 75%	..	1	„

With the exception of the coronary sinus, almost all possible sites of selective injection have been employed, including the aorta, all four chambers, the point of passage through a septal defect or a patent ductus and, with smaller injections, well away from impaction point, the pulmonary veins. The site most frequently used has been the right ventricle, preferably with the catheter tip freely mobile and directed upwards at the lower end of the outflow tract.

In contrast to the practice of many investigators, injections into the pulmonary artery have been infrequent and it is possible that this may have played a part in avoiding complications. We are certain that avoiding full anaesthesia has contributed significantly to safety. In all these cases examination has been carried out under sedation only.

The lower viscosity of triosil makes rapid injection easier (Busfield, Child, and Tomich, 1962; Pattinson, 1962). Hypaque and triosil appear to be equally safe, and once their safety has been conceded the advantages of the combination of multiple contrast injections and cine-radiography need no emphasis to anyone who has employed them. With this additional freedom cardiac catheterization and angiocardiology combine to give much more information, especially when oximetry provides immediate knowledge of oxygen saturations and a television viewing system enables good monitoring of the behaviour of the contrast medium during the course of each run of cine film. This immediately available information guides the subsequent stages of investigation.

It is useful to be able to use advantageous injection sites which the catheter may reach perhaps only once during the course of the examination. It is also useful to be able to employ projections that are not at right angles to each other, particularly oblique views. A well-rotated left anterior oblique projection, giving an end-on view of the ventricular septum, is especially informative about a transseptal flow in either direction; an almost frontal right anterior oblique projection gives a good view of the right ventricular outflow tract and pulmonary valve.

ILLUSTRATIVE CASES

The following brief extracts from case histories are quoted to illustrate some of the ways in which multiple injection technique can be adapted to the particular needs of the problem under investigation. Some are illustrations of simple investigations in which few contrast injections are required, and the examination perhaps only substantiates or amplifies information already available; others are instances of the value of more numerous injections and the sometimes crucial role of the information provided.

Case 1. Body weight 23 kg. The clinical and direct x-ray evidence of pulmonary stenosis was confirmed by catheterization which showed a pressure gradient of 75–85 mm. Hg across the pulmonary valve. A contrast injection of 33 ml. triosil 75 per cent was made into the right ventricle in the right anterior oblique projection with only slight rotation from the postero-anterior projection (Fig. 2A and B). The first contrast medium to pass through into the pulmonary artery did so in the form of a jet, indicating the size of the stenotic orifice. Beyond this there was post-stenotic dilatation and a deep supra-valvar recess. There was also muscular hypertrophy in the right ventricular outflow tract without severe infundibular stenosis.

No shunt in either direction was seen after the injection, so the catheter was withdrawn into the right atrium and a second similar injection made, using the well-rotated left anterior oblique position to place the septa end-on to the rays. Again no shunt was seen in either direction and a diagnosis of pulmonary stenosis without associated septal defect was confirmed at operation.

Comment. In this simple case, the angiocardiological appearance illustrated the normal anatomy and substantiated the other available information.

Case 2. Weight 20.5 kg.; this little girl tired easily. Radiographs showed slight cardiac enlargement with a very prominent pulmonary segment and some pulmonary plethora. At cardiac catheterization there was a rise in saturation in the right atrium and a second rise in the right ventricle, both confirmed by several estimations. The right ventricular pressure was slightly raised.

The catheter entered a right pulmonary vein from what appeared to be the junction of the superior vena cava and the right atrium, suggesting an anomalous insertion. When the child was turned into the left

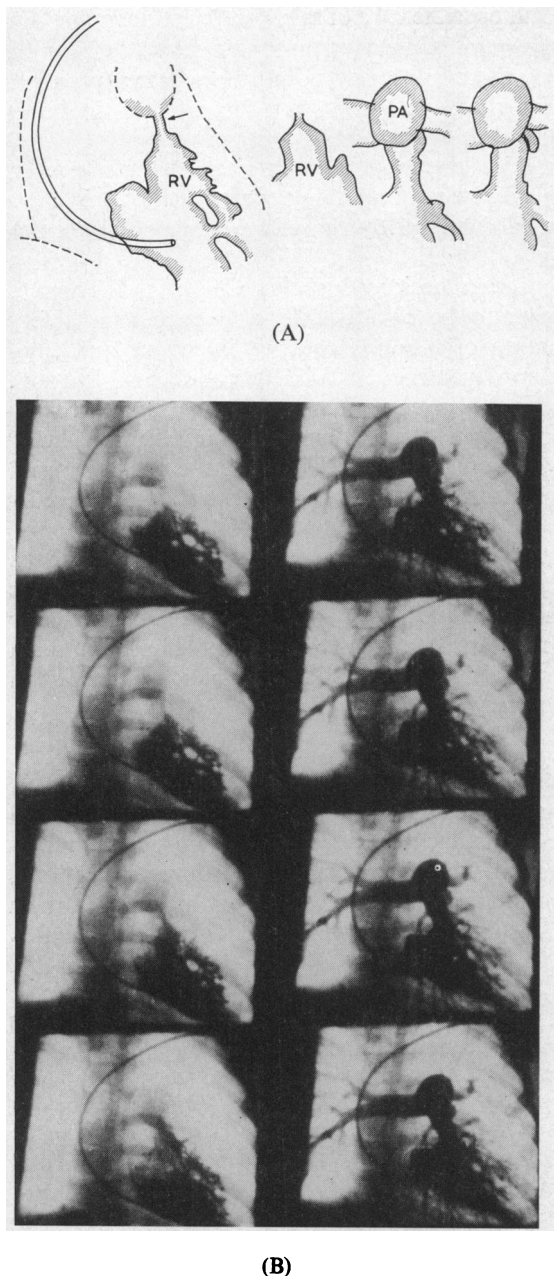


FIG. 2.—Case 1: Valvar pulmonary stenosis. (A) Tracings from cine film: injections into R.V. (right anterior oblique); (B) corresponding cine frames.

aorta and two similar injections were made, one just above the aortic valve and one higher up, in the postero-anterior and left oblique positions. These confirmed the patent ductus by a flow into the pulmonary artery as well as giving more information about the coarctation.

Thus the final diagnosis was coarctation of the aorta plus two ventricular septal defects and a patent ductus arteriosus.

anterior oblique position the catheter was then seen passing postero-superiorly for a short distance before it turned forwards into the vein, so that an anomalous insertion became less likely (Fig. 3A).

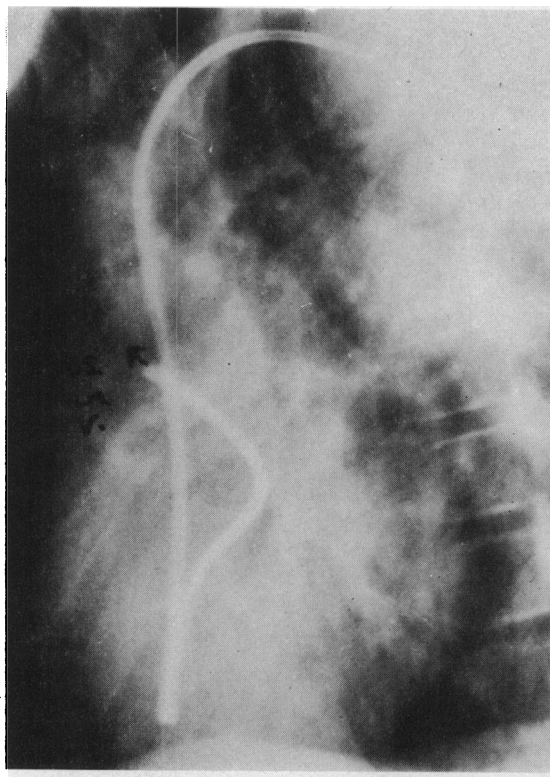
The catheter was withdrawn to the expected position of the left atrium and 20 ml. triosil 75 per cent was injected in the left oblique position. On the television monitor it was seen that the injection site was indeed left atrium, confirming that the vein did not have an anomalous insertion. There was a flow through an atrial septal defect into the right atrium.

It was now important to evaluate the *second* oxygen saturation rise, found in the right ventricle; so the catheter was manipulated into the left ventricle, keeping the same left oblique projection. Another 20 ml. of contrast medium injected here showed no transseptal flow (Fig. 3B and C); thus the rise in saturation was entirely attributable to the atrial septal defect.

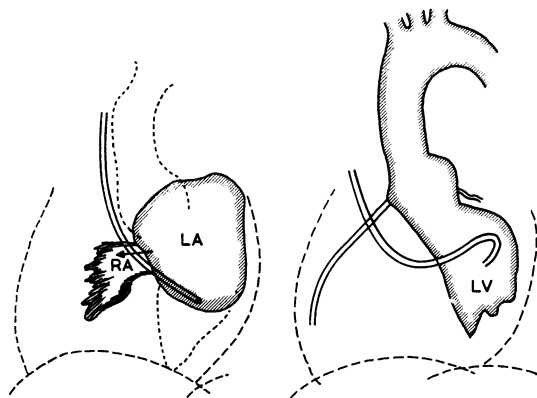
Comment. The angiocardigram proved invaluable in assessing the double saturation rise, providing a good example of the way in which contrast methods can combine with catheterization to provide a greatly improved diagnostic method.

Case 3. A girl weighing 17 kg. failed to thrive and developed cardiac failure which lasted for the first three months of life; she was dyspnoeic but not cyanosed. The blood pressure was 110/60 mm. Hg but the femoral pulses were difficult to feel. The second pulmonary sound was loud with a continuous murmur and systolic thrill. Right heart catheterization showed a 10 per cent rise in oxygen saturation in the pulmonary artery, but there was possibly also a small ($1\frac{1}{2}\%$) rise in the right ventricle where a somewhat shortened hydrogen circulation time had been recorded once. Pressures were not raised. A catheter was, therefore, passed along the right brachial artery into the ascending aorta and thence into the left ventricle. Injection of 16 ml. triosil 75 per cent in the left anterior oblique position showed two small ventricular septal defects, a tiny one in the muscular septum and a larger higher defect (Fig. 4). In addition, it showed an adult-type coarctation at the usual site in the descending part of the aortic arch.

The catheter was withdrawn to the ascending



(A)



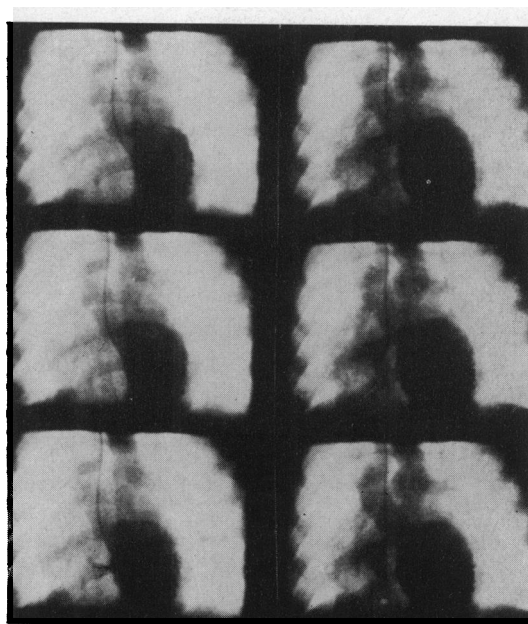
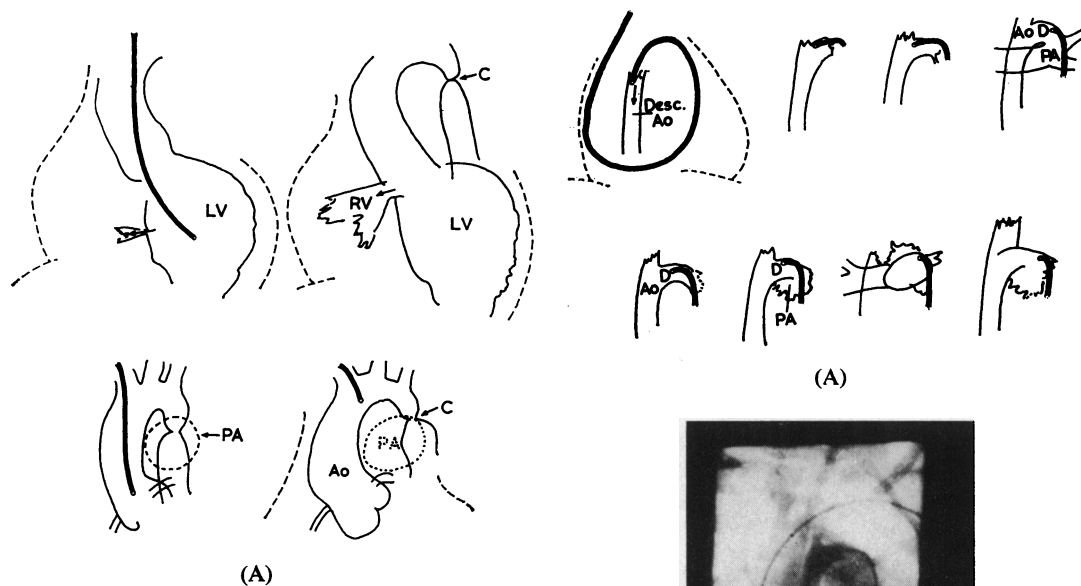
(B)



(C)

FIG. 3.—Case 2: Atrial septal defect. (A) Catheter in right superior pulmonary vein; (B) tracings from cine film: injections into L.A. and L.V. (left anterior oblique); (C) corresponding cine frames.

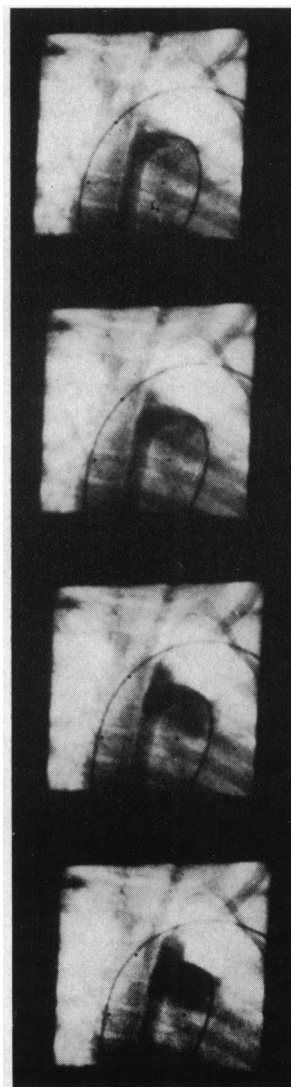
Case 4. A girl of 12.5 kg. body weight was thought to have a ventricular septal defect. At catheterization, however, there was no rise in saturation in the right ventricle but a rise of 14 per cent in the pulmonary artery. The catheter passed directly from the latter into the aorta and there was only a 10 mm. pressure gradient between the two great vessels. Two injections of 10 ml. triosil 75 per cent were made, one in each oblique position, with the catheter tip just into the aorta and withdrawing it during the injection. The large ductus was well seen in the right oblique projection (Fig. 5). A third injection (15 ml.) was made into the right ventricle in the left oblique position. This showed the typical primary and secondary dilution defects of a patent ductus (Astley, Parsons, and d'Abreu, 1959), but there was no reverse shunt. A final



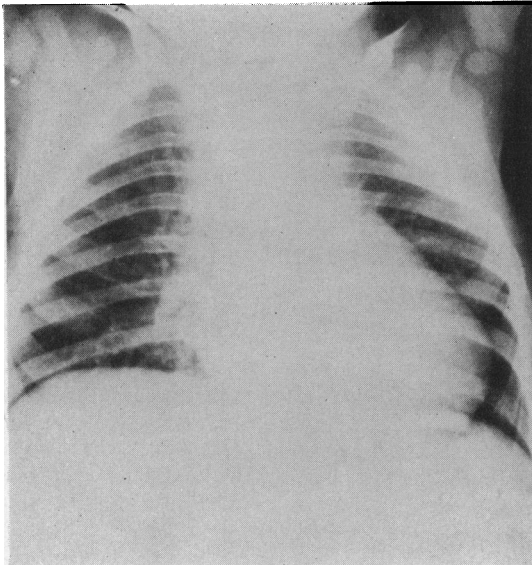
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FIG. 4.—Case 3: Coarctation, two ventricular septal defects, patent ductus arteriosus. (A) Tracings from cine film: injections into the L.V. and aorta (left anterior oblique); (B) corresponding cine frames.

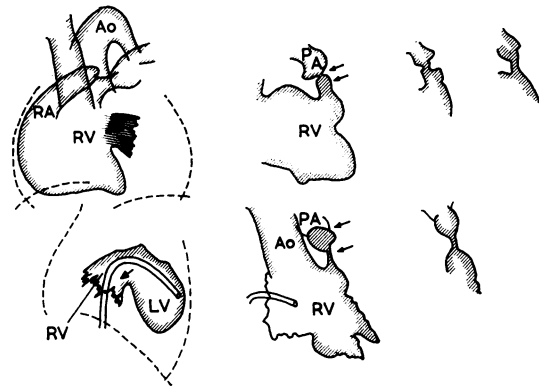
FIG. 5.—Case 4: Patent ductus arteriosus. (A) Tracings from cine film: injections into aorta while withdrawing catheter to P.A. (right anterior oblique); (B) corresponding cine frames.



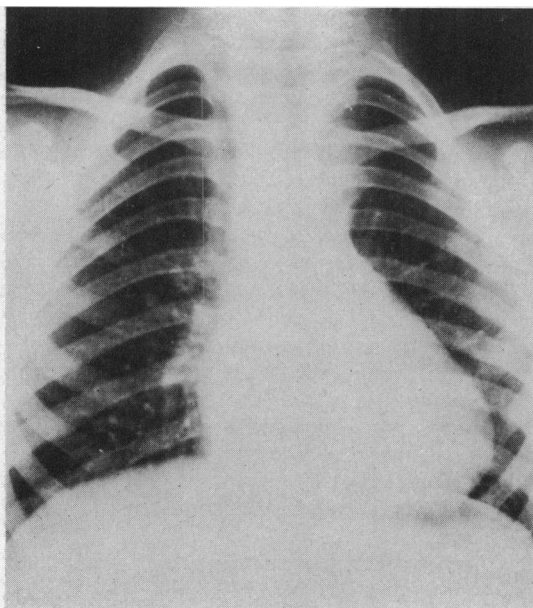
(B)



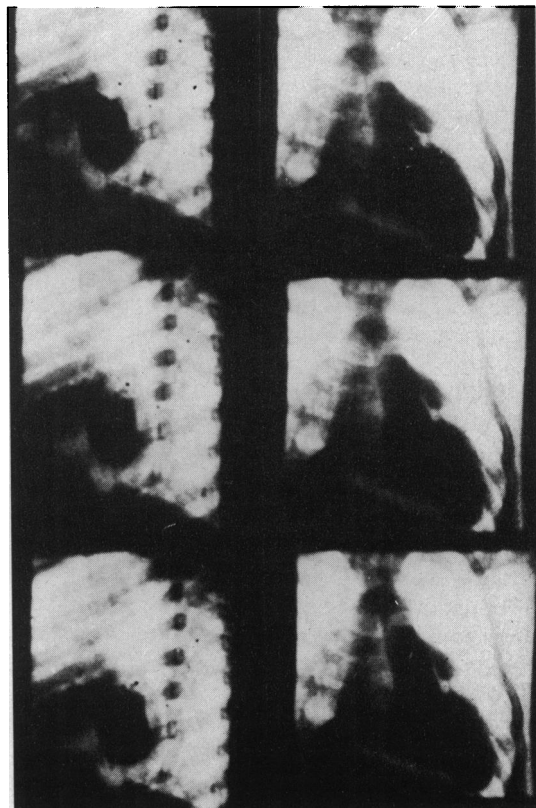
(A)



(C)



(B)



(D)

FIG. 6.—Case 5: Fallot's tetralogy. (A) Age 1 year, a little pulmonary plethora; (B) age 4 years, pulmonary oligæmia; (C) tracing from cine film. *Top row*: venous angiogram at 1 year; *bottom row*: selective examination at 4 years; (D) frames from cine film at 4 years (left and right anterior obliques).

diagnosis was made of a large ductus arteriosus with nearly balancing pressures but no reverse shunt under the conditions of the investigation. At operation, after closure of the ductus, the pulmonary artery pressure dropped to a normal level.

Comment. In most children the diagnosis of a patent ductus is established by physical examination, and catheterization is not necessary. In babies where the physical signs may be less clear cut, a venous cine-angiogram, with two injections via a nylon catheter inserted high up into the arm, provides a simple, quick, and safe method of differentiating between a ductus and a septal defect (Astley, 1957). The same method can be applied in older children, though it is rarely necessary. Full investigation by catheterization and selective angiocardiology is necessary only in a small proportion of children, usually when pressures in the two circulations are approaching balance, as in the example just described. When full investigation does become necessary, demonstrating a ductus by contrast injection during withdrawal of the catheter from aorta to pulmonary artery is particularly effective. It is, of course, a method that is only practicable with rapid rates of radiography, such as those given by cine methods.

Case 5. A boy weighing 10.5 kg. had lately become slightly cyanosed and dyspnoeic. Radiological examination showed a little pulmonary plethora but a rather flat left middle segment (Fig. 6A). At this time a venous cine-angiogram was performed with injections in two oblique projections. This showed mild Fallot's tetralogy (a bidirectional shunt through a considerable-sized ventricular septal defect, a moderate infundibular stenosis and a small pulmonary valve). As the general condition of the child was good, operation was deferred and he was readmitted at the age of 4 years. Cyanosis had increased and he only weighed 13.5 kg. There was now a distinctly subnormal lung vascularity (Fig. 6B).

He was catheterized from the groin. There was no rise in saturation in the right ventricle and the pulmonary artery could not be entered. However, the catheter passed through the foramen ovale into the left atrium and then into the left ventricle. 14 ml. triosil 75 per cent were injected here in the left oblique position, showing a rather large high ventricular septal defect. Then 18 ml. were injected into the right ventricle in the slightly right oblique position. There was a large shunt into the right arching aorta and a poor flow to the lungs. There was a very narrow infundibular lumen and a small pulmonary valve (Fig. 6C and D). Compared with the earlier venous angiogram, the stenosis appeared more severe.

Comment. This is an example of the routine use of multiple injections in Fallot's tetralogy, with the added interest that progressive stenosis was demonstrated. It is interesting to note how the chance introduction of the catheter into the left atrium could be utilized and how the disadvantage of being unable to pass the catheter through the severe stenosis was nullified. It is also notable that, certainly in small children, a venous cine-angiogram gives practically as much significant information as the much more time-consuming selective examination.

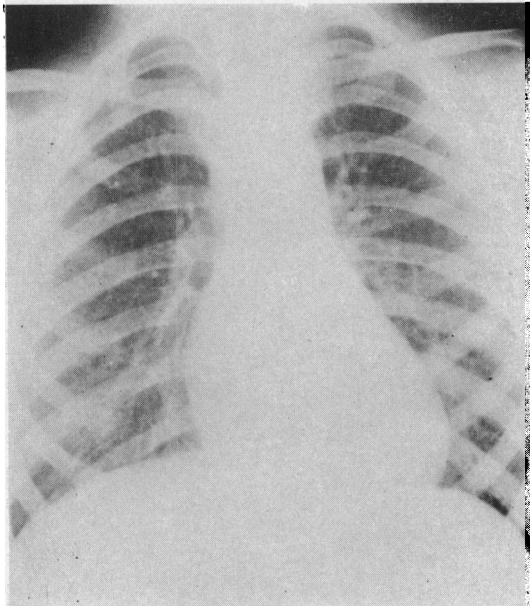
Case 6. A girl, 15 kg. body weight, was dyspnoeic and cyanosed. Radiological examination showed an appearance somewhat suggestive of Fallot's tetralogy, with poorly vascular lungs (Fig. 7A). However, there was a slight prominence on the left mediastinal border above the concave left middle segment.

Catheters passed from the groin would not enter either great vessel but there was an 8.5 per cent saturation rise in the right ventricular outflow tract. The left atrium was entered from the right and an injection of 14 ml. triosil 75 per cent was made here in the left oblique position (Fig. 7B and C). This showed a small left-to-right shunt at atrial level and also a high ventricular septal defect. The curve of the aortic arch appeared foreshortened in this projection, suggesting the type of aortic origin seen in corrected transposition, which would of course explain the left superior mediastinal prominence seen in the chest radiograph. An injection of 20 ml. into the right ventricle in the right oblique position caused both aorta and pulmonary artery to fill, their origins being very close together. The observation of this proximity on the television monitor indicated the need for further study and two more similar injections were made, using the postero-anterior and left oblique positions. In these views the aortic and pulmonary origins were still very close together and the ventricular septal defect was well seen in the left oblique view. The aorta arose to the left of the pulmonary artery and there was a valvar pulmonary stenosis.

Thus the final diagnosis was a complicated variation of Fallot's pentalogy, with unusual proximity of the origins of the great vessels, amounting to a double outlet right ventricle.

Case 7. A very blue baby, 4.25 kg., was in cardiac failure. Angiocardiology was carried out as a matter of urgency. Two venous injections of 6 and 4 ml. of triosil 75 per cent were made through a nylon catheter inserted into the right arm, with cine-radiography in both oblique projections.

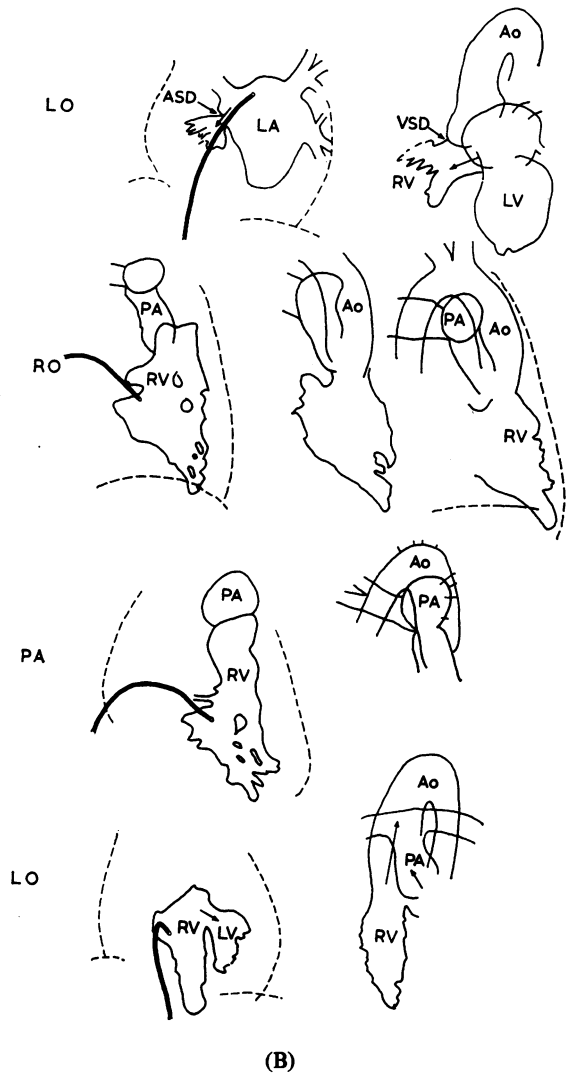
The right heart emptied quickly via the aorta, which arose anteriorly (Fig. 8). No pulmonary artery could be seen arising from the right ventricle. Since the lungs were plethoric on direct radiography, this could only mean that the pulmonary artery arose from the left ventricle. Under the aortic arch a patent



(A)



(C)



(B)

FIG. 7.—Case 6: Double outlet right ventricle. (A) Pulmonary oligæmia; slight prominence to left above concave pulmonary segment. (B) Tracings from cine film. *Top row:* injection into L.A. (left oblique) shows a small A.S.D. and a high V.S.D. *Second row:* injection into R.V. (right oblique) shows filling of both great vessels from R.V., their origins close together. Valvar pulmonary stenosis. *Third row:* injection into R.V. (frontal projection). Great vessel origins close together, the aorta to the left of the P.A. *Bottom row:* injection into R.V. (left oblique). Ventricular septal defect; close origin of great vessels. (C) Cine frames: injections into L.A. (left oblique) and R.V. (right oblique).

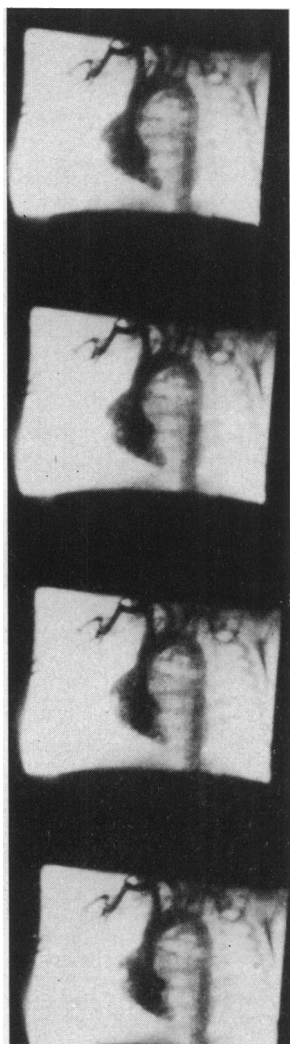
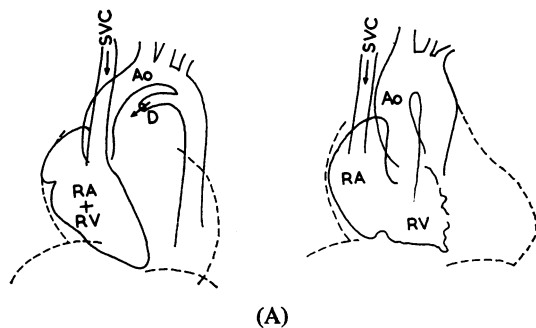


FIG. 8.—Case 7: transposition of great vessels; patent ductus arteriosus. (A) Tracings from cine film: high venous injections (left and right anterior obliques). Anterior origin of aorta; no P.A. arising from R.V.; filling of ductus. (B) Cine frames (left anterior oblique).

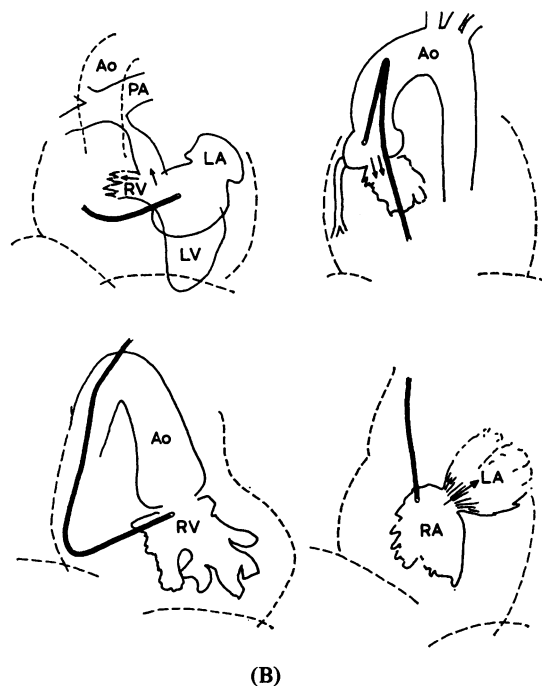
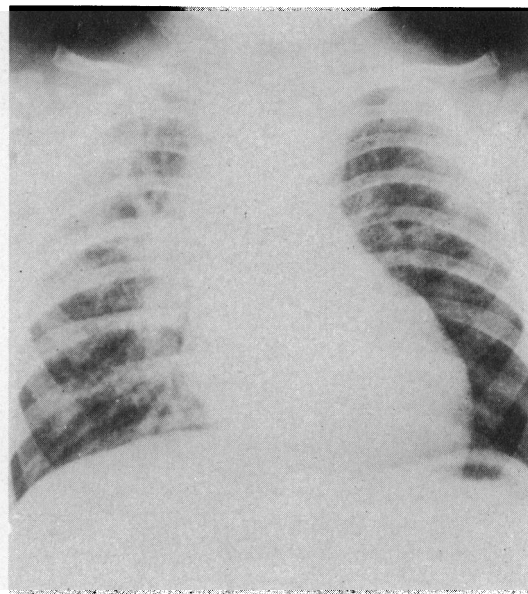


FIG. 9.—Case 8: transposition of great vessels; pulmonary stenosis; atrial and ventricular septal defects. (A) Pulmonary plethora; concave left middle segment; right arching aorta. (B) Tracings from cine film. *Top row:* injection into L.A. (left anterior oblique) shows a V.S.D.; P.A. originates from L.V. via a stenosis. Injection into the aorta shows that it originates anteriorly from R.V. *Bottom row:* injection into R.V. (right anterior oblique) confirms that the aorta and not P.A. originates from this chamber. Injections into R.A. (left anterior oblique) show a right-to-left shunt through an atrial septal defect.

ductus arteriosus led a little contrast medium into the pulmonary artery, but almost immediately it was largely pushed back into the aorta again, indicating balanced pressure in the two circulations.

The diagnosis of transposition of the great vessels was confirmed at necropsy later.

Case 8. A boy, 17 kg., suffered from attacks of dyspnoea and cyanosis and was never completely acyanotic. Radiological examination showed a slightly enlarged heart with a concave left middle segment and a right-arching aorta (Fig. 9A). Pulmonary vascularity was somewhat increased, especially on the right. At catheterization, oxygen saturations were equal in the vena cava, right atrium, and right ventricle. From the right atrium the left atrium was entered several times and saturation there was reduced. Therefore an injection of 15 ml. of triosil 75 per cent was made into the left atrium in the left oblique position (Fig. 9B). This showed that the pulmonary artery arose via a narrow channel from the left ventricle and there was a ventricular septal defect. During further manipulation of the catheter the aorta was entered from the right ventricle and a second injection was made here, also in the left oblique position. The aorta arose very anteriorly. A third injection, of 20 ml., was made into the right ventricle in the right oblique position, confirming that the aorta and not the pulmonary artery arose from this chamber. Finally, because of the reduced saturation found in the left atrium, 25 ml. were injected into the right atrium in the left oblique position. This showed a flow through a large atrial septal defect. Thus the final diagnosis was transposition of the great vessels with a pulmonary stenosis and atrial and ventricular septal defect.

CONCLUSIONS

Mainly because of improvements in the properties of contrast media, multiple injections and high total doses for angiocardiology have proved safe in our experience and have increased the accuracy of diagnosis in congenital heart disease. Two injections are often sufficient, but when the elucidation of a problem warrants it, this number can be increased. The exact methods employed can be tailored to fit the particular problem under investigation. Multiple injections allow the use of advantageous injection sites that are sometimes only reached once during the course of an investigation; they allow the use of projections that are not necessarily at right angles to one another but are of value because they demonstrate to the best advantage the particular defects present. Two injections with pictures in different projections (or two different injection sites) require less radiation than does a single injection with biplane filming using crossed grids, while the use of cine-radiography instead of full-sized films further reduces radiation dosage*.

Other technical advances, such as the ability to determine blood oxygen saturations immediately and without appreciable blood loss by the patient, and the facility of observing the course of the contrast medium on the television monitor at the same time that it is filmed have added immensely to the value of the combined procedure of cardiac catheterization and angiocardiology.

SUMMARY

In 500 angiocardiology multiple injections were used in 423. The average total dose of contrast medium (hypaque 85% or triosil 75%) was 2.9 ml./kg. There were no significant complications.

An important safety factor in angiocardiology is considered to be the avoidance of full anaesthesia.

The use of multiple injections allows cardiac catheterization and cine-angiocardiology to be combined more closely in a way that increases the information yielded.

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* One full-sized radiograph, even without a crossed grid, requires as much radiation as 40 cine frames with the apparatus used in the present study.